REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-99-

0185

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPOR
	1 November 1998	Final Technical Report 1 Jan 95 - 30 Sep 98

4. TITLE AND SUBTITLE
Nayesian Aspects of Material Failure, Engineering Reliability, and Software Integrity

5. FUNDING NUMBERS
F49620-95-1-0107

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Arlington, VA 22203-1977

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
F49620-95-1-0107

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Research on using Bayesian statistical methods and on probabilistic modeling of failure processes is described. Emphasis is on developing mathematical models for describing the growth of surface and penny shaped cracks in structural materials and on assessing the integrity of software via a new model for software. Initial work on a paradigm for information fusion is discussed and issues such as sensor reliability, sensor sabotage, adversarial sensors and sensor parleying are introduced.

14. SUBJECT TERMS
Bayesian Statistics, Failure Models, Information Fusion Material, Point Processes, Reliability, Shot-noise, Software Integrity, Stochastic Processes

15. NUMBER OF PAGES
3

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassfied	Unclassified	UL

FINAL TECHNICAL REPORT
1Jan 95 thru 30 Sep 98

BAYESIAN ASPECTS OF MATERIAL FAILURE, ENGINEERING RELIABILITY, AND SOFTWARE INTEGRITY

1. Principal Investigator: Nozer D. Singpurwalla

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Grant Number: (AFOSR) F49620-95-1-0107

2. Research Objectives:

To develop probabilistic and statistical technology to enhance the state-of-the-art of engineering statistics via a focus on problems that are of interest to the US Air Force. Specific attention is devoted to problems of reliability posed by issues of material failure, software integrity, and information fusion. The emphasis is on Bayesian ideas.

3. Status of Effort:

Current efforts have been focused along three directions: mathematical models for describing material failure due to the initiation and growth of microscopic surface, penny shaped, and spherical cracks; mathematical models for assessing and enhancing the integrity of software, and foundational issues of information fusion.

Progress has been made on each of these topics, some of which has resulted in several invited presentations at professional meetings, and some of which has resulted in technical papers that are currently under review. In the area of material failure a mathematical justification of some empirically observed results has been provided and directions for further research have been scoped out. In the area of software integrity a calculus based on binary logic which exploits the internal logic of a software's code has been outlined. With respect to information fusion, a paradigm for accomplishing it in a unified manner has been advocated and its ramifications have been discussed. A comprehensive document which describes the stochastic aspects of software failure is currently being developed; its aim is to summarize all the research that has been supported by the current grant and its predecessors.

4. Accomplishments:

A probabilistic model based on the Bernoulli process for the breaking of electrostatic bonds holding the adjacent particles of a material specimen has been proposed and developed. This model results in the Weibull distribution, as the distribution of surface and penny shaped cracks. The distribution is based on asymptotic considerations and it has been verified by empirical results. Current efforts involved developing an analogous result for spherical voids and gaps in materials. Such cracks and voids diminish the integrity of aircraft structures and impact reliability and readiness. They are also precursors to corrosion of material.

A model for tracking the reliability growth of a software system based on describing the concatenated failure rate function as the sample path of a shot-noise process has been developed. The model generalizes all the salient features of the previous models and has many other attractive properties. However it is very complex and its utilization requires inference based on a Markov Chain Monté Carlo exercise. This work is currently under review for possible publication.

A Mathematical model for sensor fusion based on the Bayesian paradigm has been proposed. Under this paradigm, previously unaddressed topics such as sensor reliability, sensor adversarial behavior, and sensor sabotage can be addressed. It has been shown that sensor consensus after several rounds of parley which has been claimed to be true in the communications engineering literature need not be so.

5. Personnel Supported:

Nozer D. Singpurwalla (Faculty)
Nicholas Lynn (Graduate Student)
Aaron Keith (Graduate Student under ASSERT)

6. Publications:

i) Chen, J. and N. D Singpurwalla (1997). Unification of Software Reliability Models via Self-Exciting Point Processes. *Advances in Applied Probability*, 29 2: 337-352.

ii) Eliasberg, J., N. D. Singpurwalla and S. P. Wilson (1997). Calculating the Reserve for a Time and Usage Indexed Warranty. *Management Science*, 43 7: 966-975.

iii) Singpurwalla, N. D. (1997). Gamma Processes and Their Generalizations: An Overview. In *Engineering Probabilistic Design and Maintenance for Flood Protection*, (R. Cook, M. Mendel, and H. Vrijling, Eds.), Kluwer Publishers, 67-73.

iv) Singpurwalla, N. D. and D. Bizup (1997). Probabilistic Aspects of Material Failure. In *Probabilistic Mechanics and Structural Reliability* (D. M. Frangopol and M. Grigoriou, Eds.), American Society of Civil Engineers, NY, 474-477.

v) Lynn, N. and N. D. Singpurwalla (1997). Burn-in Makes Us Feel Good. *Statistical Science*, 12 1: 13-19.

vi) Chen, J. and N. D. Singpurwalla (1996). Composite Reliability and Its Hierarchical Bayes Estimation. *Jour. of the Amer. Statist. Assoc.*, 91 436: 1474-1484.

vii) Lynn, N., N. D. Singpurwalla and A. F. M. Smith (1997). Bayesian Assessment of Network Reliability. *SIAM Review.* To appear.

7. Interactions/Transitions:

Currently, I am serving on the Committee for Aircraft Certification of the National Academy of Sciences National Research Council.

8. New Discoveries, Patents, Inventions: None

9. Honors/Awards: None